

# Intramedullary locking femoral nails. Experience with the AO nail

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## SUMMARY

*The AO interlocking nail was introduced to the Ulster Hospital, Dundonald in 1988 and since then has been used in over 50 patients with femoral shaft fractures. We have reviewed 45 patients with 46 femoral shaft fractures treated between June 1988 and April 1990. These included four compound fractures and 13 comminuted fractures. The results compare favourably with other series. The union rate was 98% and there were no instances of deep infection. The alternative treatment methods available are discussed along with a review of the relevant literature.*

## INTRODUCTION

The practice of intramedullary nailing to treat long bone diaphyseal fractures has been with us for at least 70 years. The principles and techniques were popularised by Gerhard Küntscher of Hamburg<sup>1</sup> during the 2nd World War and the method was eagerly adopted by orthopaedic surgeons worldwide. The "K" nail was generally inserted using an open technique although Küntscher himself was a keen advocate of the closed method. "K" nails are of course limited in their use to certain types of shaft fractures. Fractures of the middle third of the femur that are stable to shortening (i.e. transverse or short obliques) are eminently suitable for "K" nailing. Fractures that occur outside of these narrow confines had to be treated by other means until relatively recently.

In 1952 Modny developed the transfixion intramedullary nail. In 1972 Klemm and Schellmann introduced the much revised interlocking nail<sup>2</sup> and Kempf and Grosse of Strasbourg refined the technique in 1978.<sup>3</sup> This device has allowed us to extend the indications for internal fixation of femoral shaft fractures. An interlocking threaded screw is used to gain secure purchase on the proximal and distal femoral metaphysis, rendering the fracture stable to rotation and shortening. Fractures of the upper or lower thirds can now be successfully treated as can fractures with severe comminution. Allied to this development there has been renewed interest in closed nailing.

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In this paper we present our experience of using one particular design of interlocking nail — the AO nail (Arbeits-gemeinschaft für Osteosynthesefragen).

## **PATIENTS AND METHODS**

The first 45 patients treated at the Ulster Hospital using the AO interlocking nail were followed up at least until fracture union. Forty-five patients with 46 fractures were treated between June 1988 and April 1990.

There were 34 men and 11 women with an average age of 38 years. Thirty-one patients were under the age of 40 and 11 patients were over the age of 60. Twenty-three of the injuries were caused in road traffic accidents, twelve in falls, seven at work and one was due to a gunshot wound. One patient sustained bilateral femoral fractures in a road traffic accident; one patient had "prophylactic" nailing for a painful metastatic deposit and one patient had nailing following an elective osteotomy for malunion of an old femoral fracture.

Four fractures were compound; one was grade I and three were grade II.<sup>4</sup> Nine fractures were in the upper third of the femur, 25 in the middle third and 11 in the lower third. Twenty-one fractures were classified as transverse, 11 as oblique and 13 as comminuted. Fracture comminution was graded according to Winquist's classification.<sup>5</sup> For the purposes of this paper only those fractures of grades 3 or 4 have been termed "comminuted".

Fifteen patients sustained another major injury, which were all fractures, with ten patients sustaining another lower limb fracture. There were no cases of serious head injury or visceral injury.

After initial assessment, and resuscitation where appropriate, all patients were placed in traction, usually skeletal traction if there was likely to be any delay before surgery. Most patients were operated upon on the next available list. In 18 cases operation was delayed for one week or longer for a variety of reasons: seven patients developed fat embolism syndrome and in six cases the patient's referral had been delayed. Surgery was delayed for one patient because of a compound wound and in one patient conservative management had failed. In three cases there was no clear reason for delay. Overall the average interval between injury and surgery for all patients was 9.4 days. The average interval between injury and the development of fat embolism syndrome in the seven patients was 2.2 days.

## **OPERATIVE TECHNIQUE**

The patient is placed supine on a fracture table and traction is applied through a skeletal pin, either through the tibial tuberosity or the distal femoral metaphysis. The injured leg is adducted to allow access to the greater trochanter and the uninjured leg is held out of the way to facilitate imaging using the portable C-arm fluoroscope (Fig 1).

The fracture is reduced by closed manipulation and the position checked by the image intensifier. Limb rotation must be assessed clinically at this point. An incision is made over the greater trochanter and a guide wire is passed into the medullary canal of the upper femoral shaft. The wire is then guided across the fracture into the distal femoral shaft. The medullary canal is next reamed

by passing flexible reamers over the guide wire. Finally the definitive nail is passed down the femoral canal (Fig 2). Inadequate reaming can result in increasing comminution during nail placement. The smallest AO nail is 12 mm diameter and this necessitates reaming the medullary canal to at least 13 mm diameter. Reamer failure occurred in one of our cases.

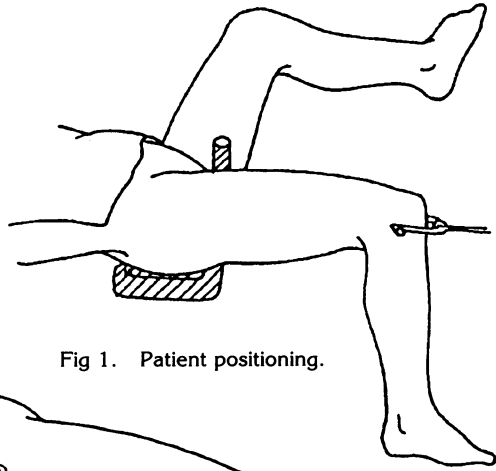


Fig 1. Patient positioning.

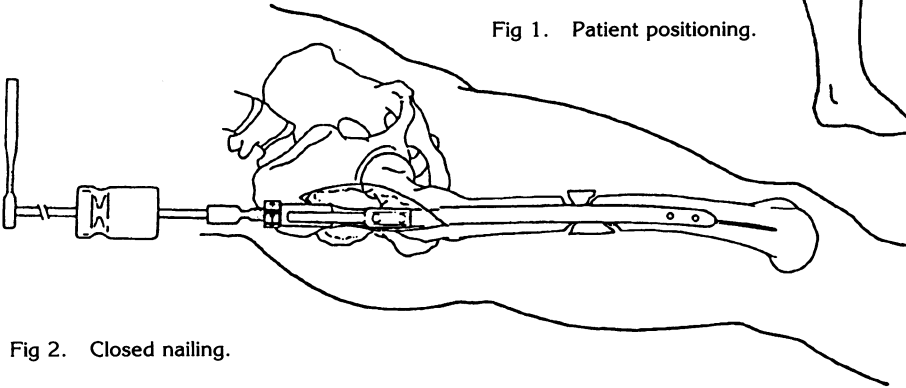


Fig 2. Closed nailing.

Occasionally the fracture site must be exposed to achieve a reduction or to allow passage of the guide wire. This is more likely to occur if surgery is delayed; 14 cases were opened in this series. In four this was unavoidable; two patients required removal of previous internal fixation, one required débridement of a compound wound and one case involved an osteotomy. In the others exposure proved necessary to facilitate a difficult reduction. For the latter group the average delay between injury and surgery was 14 days. The average delay for those cases that were not opened was six days. This difference was highly significant (Mann-Whitney test,  $p < 0.002$ ).

At this point locking can be carried out. The choice of whether to lock proximally, distally, fully or not at all is based upon preoperative assessment of the fracture and intraoperative assessment of fixation stability. In general, proximal fractures require proximal locking, distal fractures require distal locking and fractures that are comminuted often need to be fully locked. Using the AO device there are two proximal locking holes; the circular hole is used for static locking and the oval hole allows compression at the fracture site upon weightbearing (dynamization). Proximal locking is carried out using a jig attached to the upper end of the nail and consequently is fairly straightforward. Distal locking however can be very difficult.

In this series 12 cases were fully locked, six cases required proximal locking only and 15 cases distal locking only. All patients were given perioperative antibiotic prophylaxis using cephamandole. Of the cases that did not require another operative procedure the average total anaesthetic time was 105 minutes. Postoperatively patients were mobilized with the aid of crutches, and knee

bending exercises were commenced. Patients were discharged from hospital when their wounds were healed and when they were safe on crutches. All patients were followed up at regular intervals at least until union was observed. Union was felt to be established when there was adequate radiological evidence of callus formation.

## RESULTS

Thirty-five patients were mobilized on crutches, partially weightbearing, within three weeks of surgery. Of course these patients were free of all splintage immediately after surgery and most were sitting out of bed within days of operation. The ten patients whose mobilization was delayed included six patients who had other lower limb injuries, three patients over 80 years old who were frail, and one patient who required re-operation for malrotation. For these patients surgery was still beneficial; indeed multiple injuries and old age are important indications for internal fixation. Excepting the three elderly patients who never mobilized for medical reasons, the average time to mobilization was 16 days.

Twenty-six patients were fit for discharge home within three weeks of surgery. The 19 patients whose discharge was delayed included the ten who were slow to mobilize, four with other lower limb injuries, four elderly patients with medical problems and one who had a minor wound infection. Excepting the three patients who never mobilized, the average time to discharge was 22 days.

Knee movement recovered quickly in most patients. Thirty-seven patients recovered 90° or more of flexion within three months of surgery. In the other patients poor knee flexion was caused either by concomitant lower limb trauma or poor general condition. Younger patients with isolated femoral fractures recovered remarkably quickly. Some achieved a range of knee movement of 0 – 110° within ten days of surgery. The average range was 0 – 110° at 3 months. The average time to union was 14 weeks. There was one case of non-union.

Results have been graded according to the system used by Thoresen.<sup>6</sup> Twenty-nine were graded as excellent, eight were good, three were fair and two were poor. Four results were not graded including two elderly patients who died because of poor general condition, one patient who died of malignancy after discharge, and one patient who also had a compound tibial fracture. The two poor results include one case of non-union and one case of early implant failure. The three fair results include one elderly patient who never mobilized and two patients who each had 2 cm of femoral shortening.

Eleven nails have been removed after fracture union. In five cases this was carried out for hip pain and in the remainder after patient request. On average the nails were removed eleven months after their insertion.

## COMPLICATIONS

Thirty-five patients had an uncomplicated early recovery. Five patients had postoperative medical complications and five had surgical problems. Two developed minor superficial wound infections which responded to antibiotic therapy. One had a wound haematoma which required splintage, one required traction postoperatively despite full interlocking such was the marked degree of

fracture comminution, and one developed malrotation soon after surgery and re-operation was required to insert locking screws.

Late complications were seen in twelve patients. Six had significant hip pain as a result of irritation from the upper end of the nail. In all of these the nail had not been proximally locked and symptoms were probably caused by nail migration. One patient required re-impaction of the nail and the others had their nails removed after fracture union with full resolution of their symptoms.

Two patients had significant knee stiffness; both had sustained an associated knee injury. There were two cases of significant ( $> 2$  cm) shortening. In one, shortening occurred despite fully locking. The other fracture had not been fully locked, when in retrospect it probably should have been. There was one case of non-union and one case of early implant failure. There were no cases of deep infection.

## DISCUSSION

It is now well recognized that intramedullary nailing provides very stable fixation for long bone shaft fractures. The bone is splinted throughout its length and as a result postoperative displacement or angulation is prevented (Fig 3). Axial rotation and telescoping forces can however occur using unlocked nails inappropriately. The conventional nail depends for its stability on endosteal contact and interdigitation of fracture fragments. Most grip is therefore afforded where the medullary canal narrows to its isthmus at the middle third of the shaft. Fractures towards the ends of the shaft, or comminuted fractures, will not be held by a conventional nail (Fig 4). The addition of interlocking screws, however, effectively controls these otherwise difficult fractures. The screws are threaded through both intact cortical bone and the nail itself, thereby controlling both malrotation and shortening.

Nevertheless some surgeons have been reluctant to adopt this particular operative procedure because of the many technical difficulties associated with it.<sup>7</sup>



Fig 3. Comminuted shaft fracture after nailing.

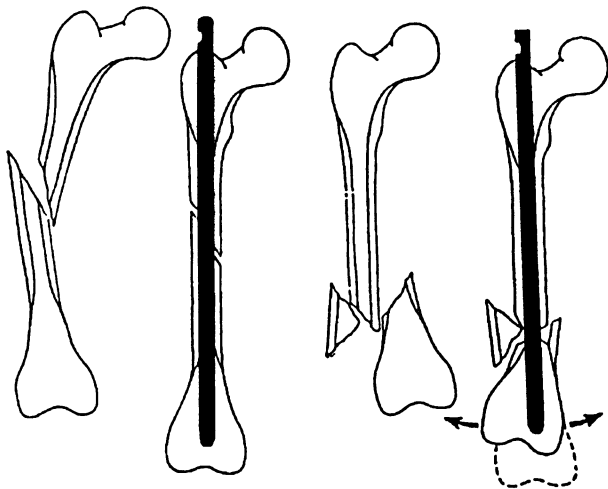


Fig 4. Fracture patterns.

The surgery is protracted and demanding. Our anaesthetic times confirm this, and similar times have been reported for early experience in other units. The closed reduction and passage of the guide wire can be very difficult and depend on proficient use of the fluoroscope as much as accurate surgery. Distal interlocking can be particularly tedious and with it the risk of exposure to X-rays increases. Most surgeons have now adopted the "freehand" technique for distal targeting, but this still depends on perfect alignment of the fluoroscope prior to targeting. Several workers have reported X-ray exposure times in excess of 10 minutes per operation,<sup>8</sup> but if modern equipment is used, this should be reduced to well under 20 seconds.<sup>9</sup>

Grosse and Kempf originally recommended dynamization of their nails after 12 weeks by removing the locking screws. This should enhance fracture compression and promote union, but other workers have since refuted this statement.<sup>10</sup> Our case of non-union initially had this fracture plated in another hospital: after early implant failure this was revised to a fully locked nail. He was lost to follow up for 15 months, and then presented with nail fracture at the site of established non-union. In this case the rigidity of the system might have contributed to non-union, and with hindsight dynamic locking would have been more appropriate. Union rates are remarkably good in most reported series. It must be remembered however that the patient can be rehabilitated long before union occurs. Some patients develop a false sense of security and return to work (unadvised) within two months of injury.

The results of interlocking nails compare favourably with either plating or conservative treatment of femoral fractures. Conservative management by traction followed by cast-bracing is still regarded by many surgeons to be a sure and safe method of treatment. However, hospitalization and recovery are prolonged and there tends to be a high rate of malunion. Hardy has advocated early cast-bracing resulting in fairly quick discharge from hospital. However, over 10% of his reported patients had femoral shortening of over 2 cm and 40% over 1 cm.<sup>11</sup> In an earlier study Rokkanen showed the benefits of nailing over conservative management resulting in a 23% higher rate of full mobility one year after surgery; these differences were more marked in older patients.<sup>12</sup>

During the 1960's it became popular to treat femoral shaft fractures by plating. The advantages of management without traction were obvious but local complications were common. In one study, Rüedi reported a 6% incidence of bone infection after plating closed comminuted fractures.<sup>13</sup> There was a 7% implant failure rate and a 7% rate of delayed union: the overall functional results were good but many surgeons today would regard the rate of local complications as prohibitive. More recently Böstman of Helsinki, in a controlled series, has shown a significantly increased incidence of local complications following plating of femoral shaft fractures when compared with nailing.<sup>14</sup> It is now known that plating disrupts the periosteal blood supply of the fracture fragments and can result in disturbances of fracture healing. Conversely intramedullary reaming and nailing disrupt the endosteal vasculature, but this does not appear to affect significantly the cortical blood supply.<sup>15</sup>

The advantages of closed nailing over open operation continue to be debated. In theory if one disturbs the fracture haematoma by exposing the fracture site,

healing will be delayed and the risk of infection will be increased. Rokkanen reports slightly better results for closed nailing over open nailing<sup>12</sup> but in a more recent and better controlled study, Leighton did not find any significant difference.<sup>16</sup> There have been several papers advocating the use of locked nails for compound fractures. Chapman in 1986 suggested delayed closed nailing (after wound healing).<sup>17</sup> More recently, however, Brumback reported on 46 grade III open fractures. He concluded that infection was not increased when early nailing was compared with delayed operation.<sup>18</sup>

Infection remains one of the most serious complications. Most series have reported a small rate of deep infection and we were fortunate not to see any cases. There was one case of early implant failure illustrating one of the weaknesses of this particular implant design. The nail fractured through one of the proximal locking holes which was at the level of the subtrochanteric fracture (Fig 5). It is felt that the transverse lie of the proximal locking holes might result in an area of weakness.<sup>19</sup> Revision was carried out using a Grosse-Kempf nail.

From our series it is evident that there is room for improvement in several areas. In particular the delay between injury and surgery was much longer than that reported by others. A number of factors combine to explain this. One surgeon carried out most of the operations, which resulted in unavoidable delay for some patients. Also, in many patients surgery had to be delayed because of respiratory complications necessitating treatment in the intensive care unit. Our rate of respiratory complications was much higher than in comparable series. It is now felt that early surgery reduces the incidence of fat embolism syndrome.<sup>20</sup> In addition to reducing early morbidity, early surgery has been associated with quicker overall recovery. Eriksson demonstrated a much faster return to pre-injury function following early nailing when compared with delayed nailing.<sup>21</sup>

In summary, interlocking nails have allowed us to extend the hitherto limited indications for internal fixation of femoral shaft fractures. The operation gives a good technical result, allied to early mobilization and discharge for the patient. Union rates are high with a low rate of complications. Hitherto the technique has appealed largely to enthusiasts. Nevertheless it should now be made available to all patients with fractured femoral shafts, especially elderly patients. The service would be improved by earlier referral, and earlier surgery.



Fig 5.  
Implant failure four weeks postoperatively.

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